

Application of Cultural Databases in Site-Specific Clutter Modeling

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Overview

- Spatial information challenges
- Survey of image and database sources
- Image registration and processing
- Modeling methodology
- Site-specific modeling - MCARM scenario example
- Application in KASSPER framework
- Computing and implementation considerations
- Summary

Data Characteristics

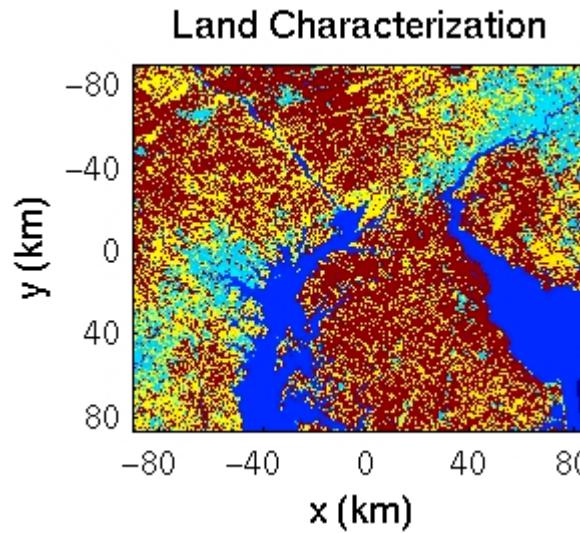
- Various projections
- Different scales and base map sizes/shapes
- Different formats
 - Raster
 - Vector
- Various distribution formats and standards

Challenges

- Registration at common reference point
- Choice of appropriate projection
- Processing and fusion in efficient environment

Land Characterization Data Sources

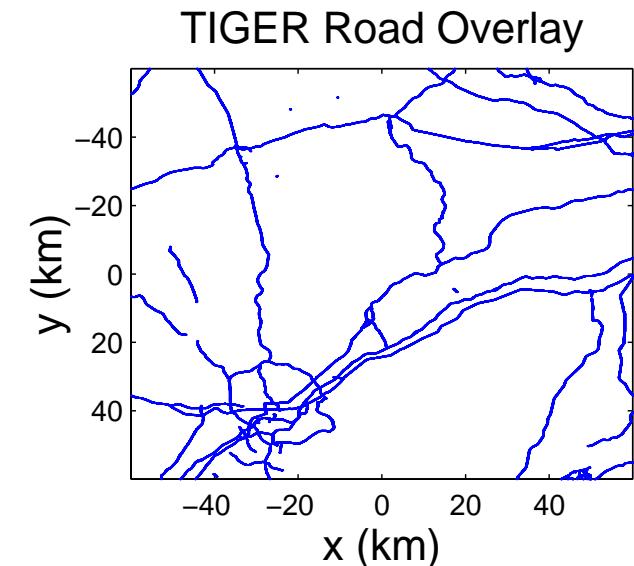
- LULC (Land Use/ Land Cover)
 - USGS
 - Approximately 90 m resolution
 - Older data set, used primarily for historical reference of land use
 - Data Transfer Format: GIRAS (Vector), CTG (Raster)
 - Projection: UTM



- NLCD (National Land Characterization Data)
 - 30 m resolution
 - Available for entire US
 - Albers Equal-Area Conic Projection
 - Data Transfer Format: Binary
 - Image size/shape: State

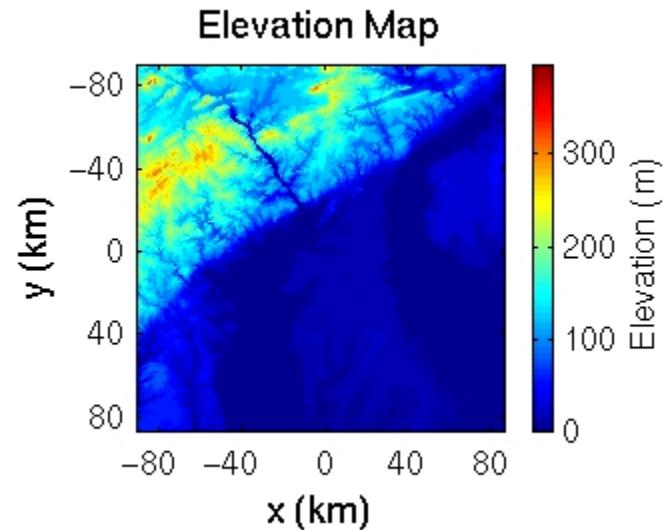
Transportation and Cultural Features

- TIGER
 - Source: US Census Bureau
 - Census Feature Class Codes (CFCC)
 - Includes: Transportation, cultural features and hydrography
 - UTM Projection
 - Size/ Shape - County
 - Format: Vector in TIGER record type files
- Additional Sources:
 - DLG (Digital Line Graphs)
 - Source: USGS
 - Transportation, hydrography, cultural features, and hypsography
 - DFAD
 - Source: NIMA



Digital Elevation Data

- Digital Elevation Models (DEM)
 - USGS
 - Resolutions available: 90 m, 30 m and approximately 10 m
 - Based on fusion of several data sources
 - Format: DEM and SDTS
 - Geographic coordinates
- Digital Terrain Elevation Data (DTED)
 - NIMA
 - Several resolutions, including approximately 100 m and 30 m
 - Images distributed in geographic coordinates
 - Available for much of US, but gaps in data



Projections

- Every flat map misrepresents the surface of the earth because projecting a 3D surface onto a 2D surface
- Although over 200 projections exist, only a few are widely used
- Projections differ in the amount and type of distortion introduced. No projection can preserve all of the following characteristics:
 - Direction
 - Area
 - Distance
 - Shape
- Although all projections distort the earth, different projections enable preservation of these properties in parts of the map or in the entire map
- Each projection has an associated datum and reference ellipsoid

Projections

- Categorized based on the following [1]:
 - Projection Surface: Plane, Cone, Cylinder
 - Case or Orientation: Tangent or Secant
 - Aspect: Normal, Transverse, Oblique
 - Light Source Position
- Normal Tangent Projections (Figures from [1])

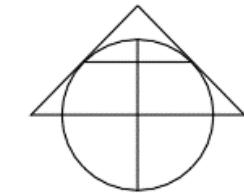
Cylindrical



Azimuthal

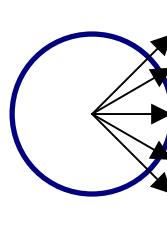


Conic

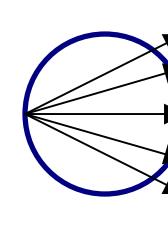


- Perspective projections use a different position of a light source cast onto the globe

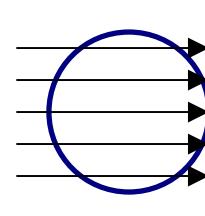
Gnomonic



Stereographic



Orthographic



Azimuthal Equidistant

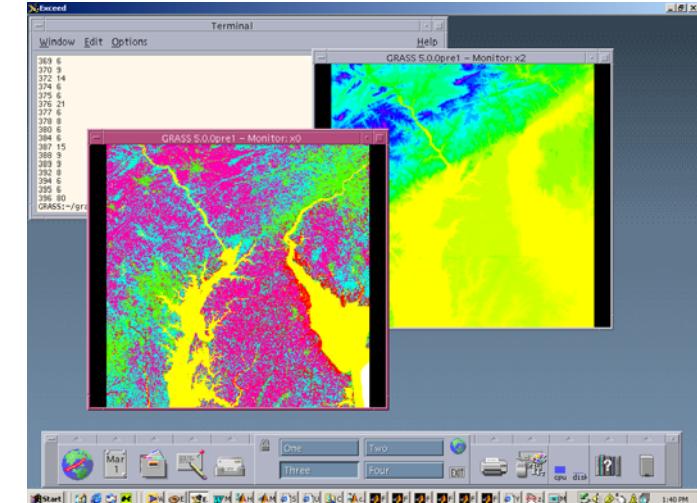
- The three perspective projections distort distances
- The Azimuthal Equidistant Projection accurately renders distances from the center of the projection by modifying the spacing of parallels to equal-spacing
- Used in radio and seismic propagation problems
- Properties
 - Distances and directions are true to all points from the projection center
 - Distances are only correct along straight lines through the projection center
 - Distortion of areas and shapes increases away from the projection center
- Supply the longitude and latitude of the projection center to specify the Azimuthal Equidistant Projection

A Couple Common Projections

- Alber's Equal-Area Conic Projection (Used with NLCD data)
 - Define the projection with:
 - Two standard parallels - 29.5 and 45.5 degrees North Latitude for NLCD
 - Origin of Projection - 96 West Longitude and 23 North Latitude for NLCD
 - No distortion along standard parallel lines and distortion increases as move away from standard lines
 - Particularly good for mid-latitudes with large east-west extent, such as the United States
- Universal Transverse Mercator (UTM)
 - Mercator and Transverse Mercator
 - Standard line is the equator or a meridian - distortion increases at increasing rate as move away from the standard line
 - Universal Transverse Mercator (Based on the Transverse Mercator)
 - 60 zones between 84°S and 84°N are created and each UTM zone has its own central meridian [2]

GIS/ Image Processing Environment

- Advantages of a Geographic Information System (GIS)
 - Scalable – e.g. when including larger, higher resolution, or more information sources
 - Structured environment
 - Allows efficient query and connection to relational databases through ODBC or native database API
- GRASS
 - Geographic Resources Analysis Support System
 - Originally developed by USA-CERL (US Army Construction Engineering Research Laboratories)
 - Contains several libraries of functions, including ability to integrate new libraries
 - Available under the GNU GPL



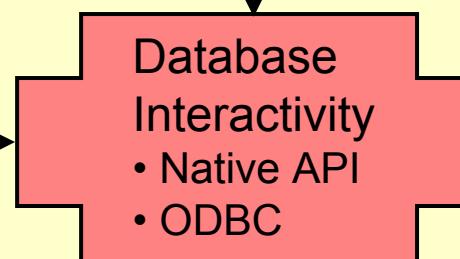
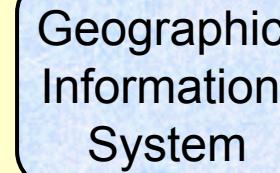
Database and Database Interactivity

- Relational Database Management System
 - PostgreSQL
 - Descendent of INGRES and POSTGRES developed at the University of California Berkeley
 - Opensource
 - Pgaccess - Graphical front-end to PostgreSQL
 - Oracle, SAS, and many other relational database systems available
- Database Interfaces
 - Native GIS API
 - GRASS and other GIS offer native database interface libraries
 - GRASS offers native interface capability to PostgreSQL
 - ODBC (Open Database Connectivity)
 - Specification for providing a predictable API to access data sources
 - An ODBC Driver must be available for the data source to be accessible
 - PostgreSQL ODBC drivers are available for several platforms

Knowledge Assistance Framework

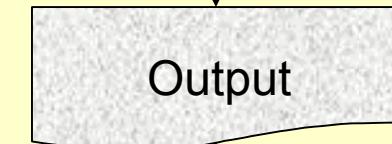
Front-end Architecture

- Cultural Databases
- Spatial Information Sources
- Radar Platform Information (e.g. INU, GPS)



Signal Processing and STAP

- Signal Processor:
- On-Board processor
 - Matlab



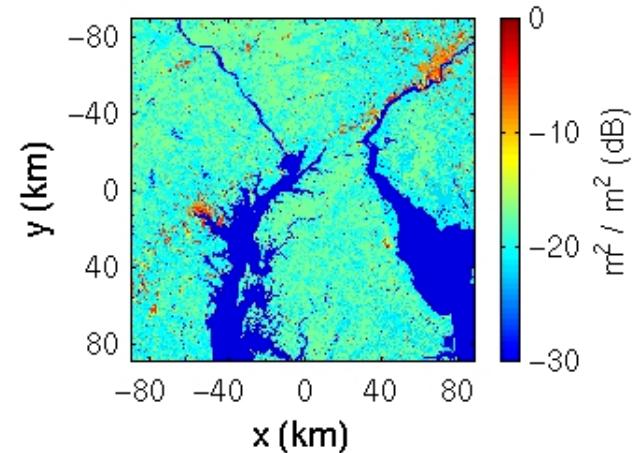
Motivation - Clutter Heterogeneity

- STAP Assumes homogeneous, i.i.d. clutter environment
 - i.i.d. secondary data places an upper bound on performance
 - Performance degradation expected in heterogeneous environments
- Clutter heterogeneity effects
 - SINR loss and test statistics vary depending on choice of sample support
 - Adding samples to the covariance matrix does not guarantee asymptotic convergence to the true covariance matrix
- Environmental and scenario-specific knowledge helps to
 - Quantify effects of heterogeneous clutter in a controlled environment
 - Mitigate effects of heterogeneous clutter in STAP applications through the following mechanisms:
 - Use *a priori* information for selection, omission, or use of degrees of freedom in covariance matrix estimation
 - Place constraints in adaptive filter design (e.g. place nulls *a priori*)
 - Pre-filtering

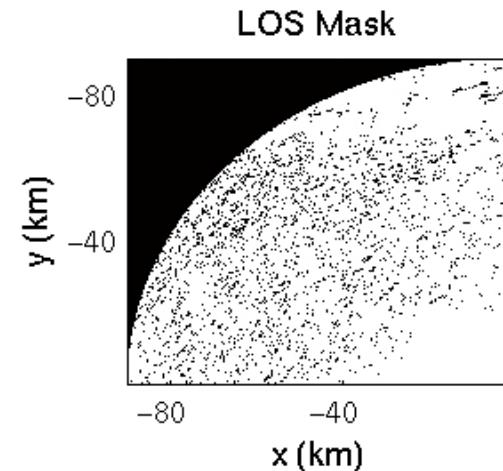
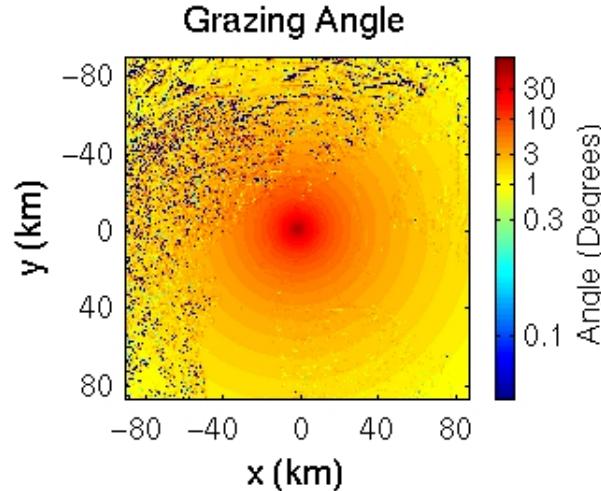
Modeling Methodology I

- Reclass 92 NLCD categories to normalized reflectivity parameters

No.	Category	γ (dB)
11	Open Water	-27
12	Perennial Ice/Snow	-9
22	High Intensity Residential	-8
42	Evergreen Forest	-12
82	Row Crops	-17
91	Woody Wetlands	-20

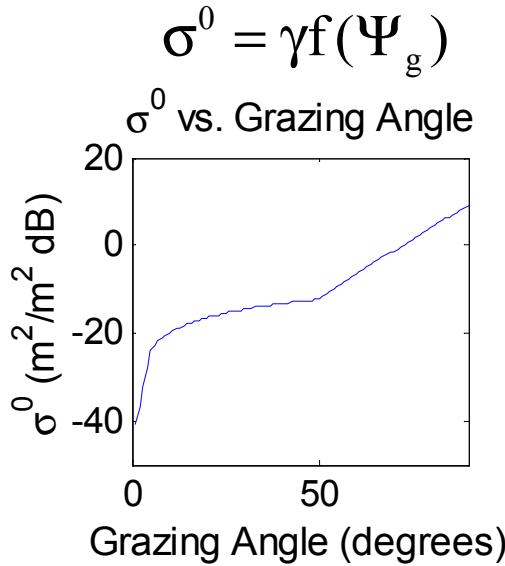


- Determine grazing angle and LOS from elevation data

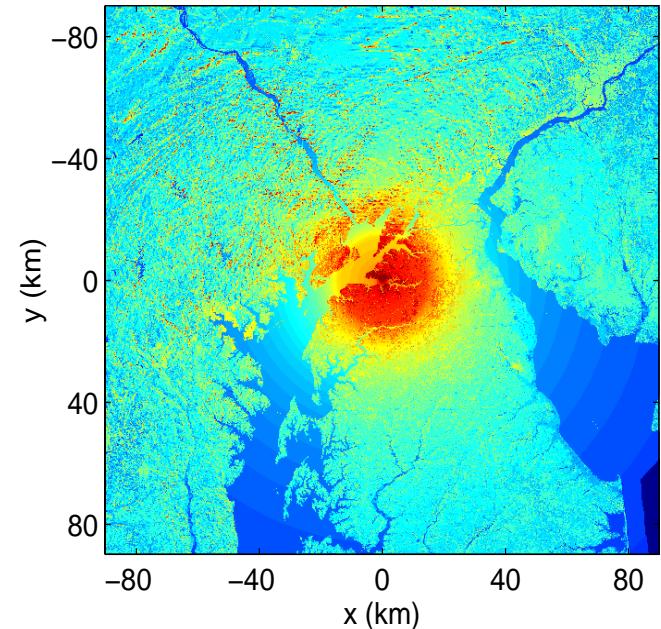


Modeling Methodology II

- Fuse map and spatial inputs into cross section per unit area of illuminated surface (m^2/m^2) σ^0
 - Use normalized reflectivity γ and σ^0 vs. grazing angle dependence
 - Including patch area yields clutter patch RCS σ

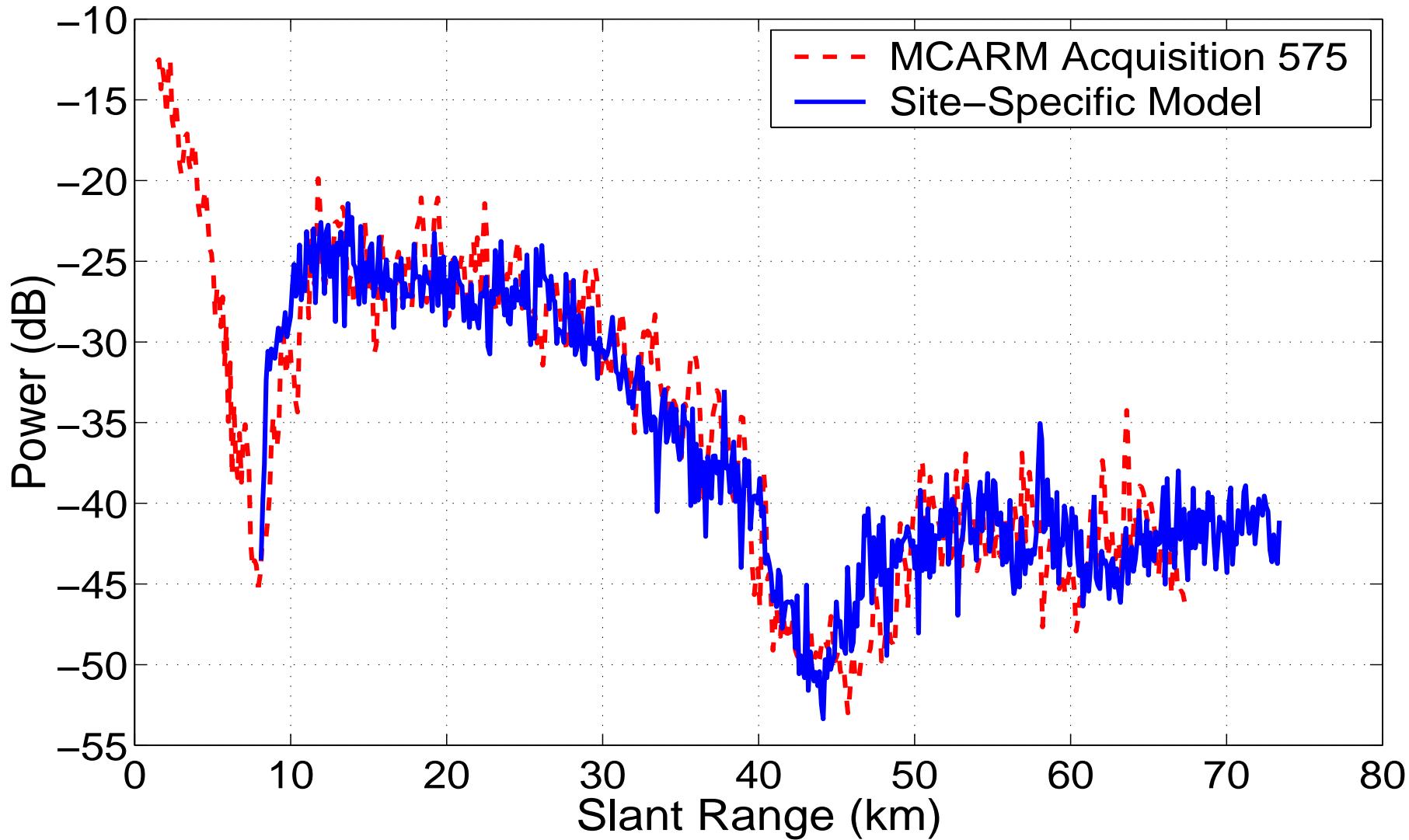


$$\sigma = \sigma^0 A_{\text{patch}}$$

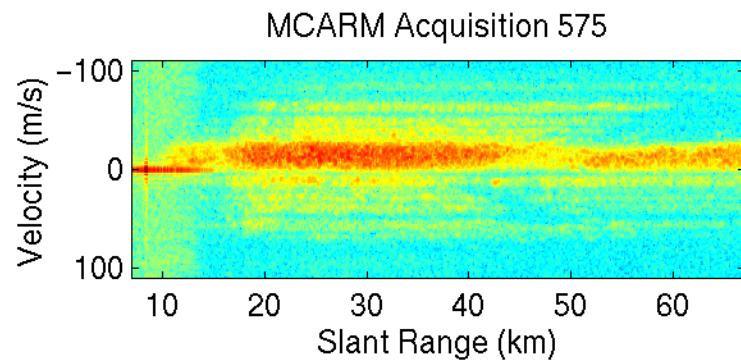
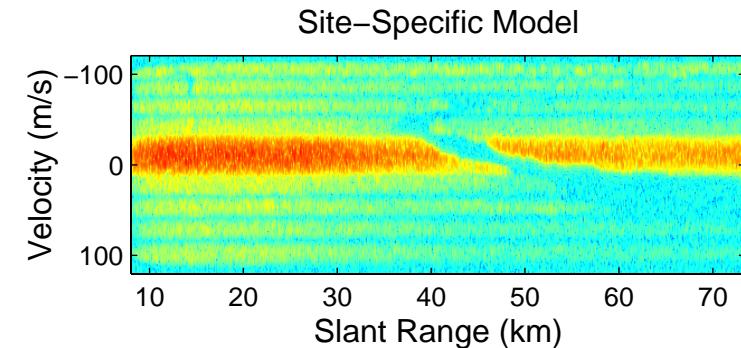
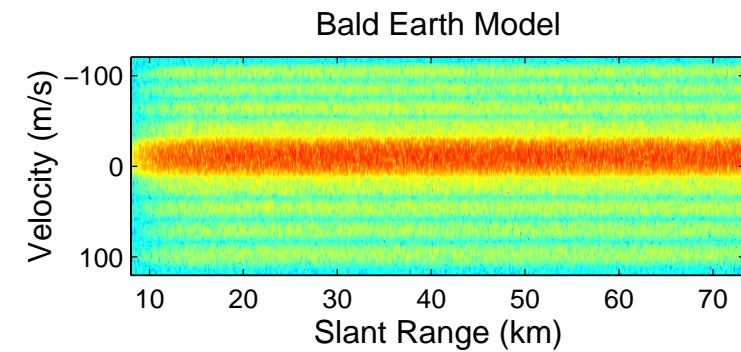
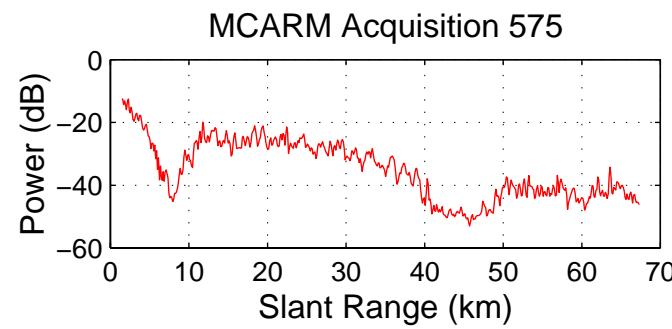
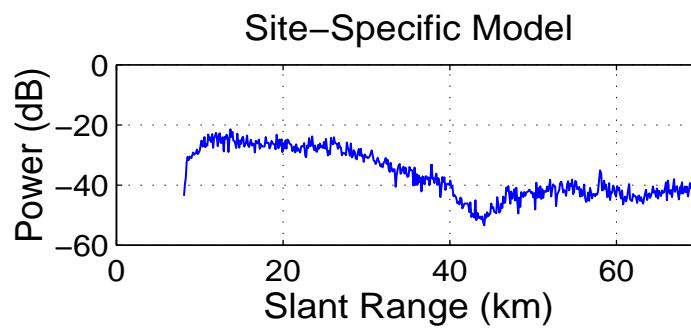
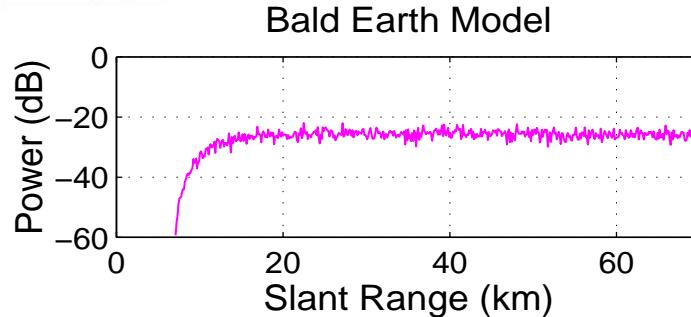





Power Vs. Range

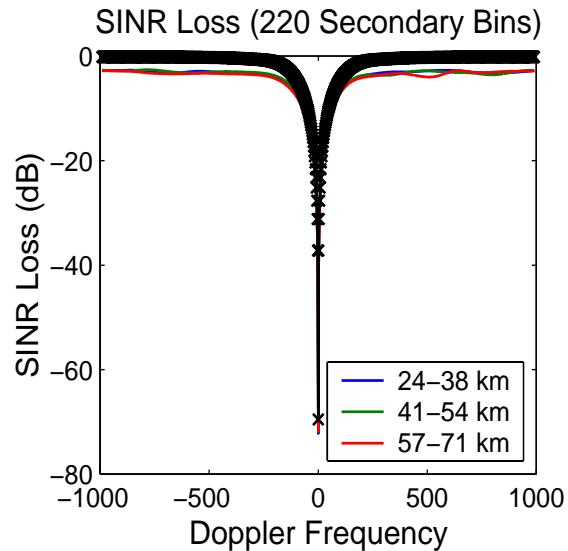


Power vs. Range and Range-Doppler Maps

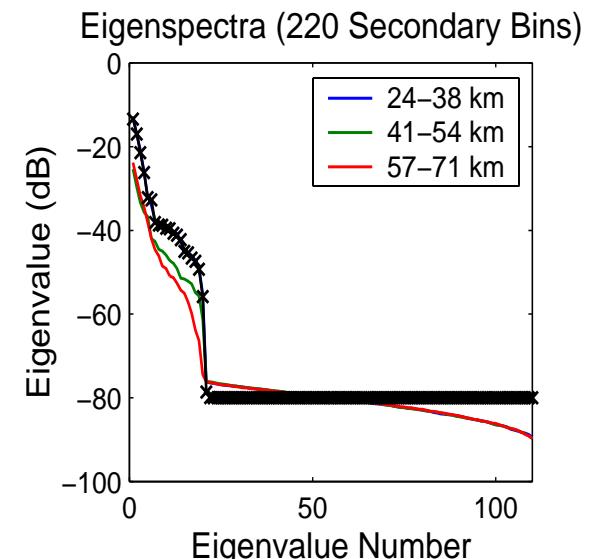
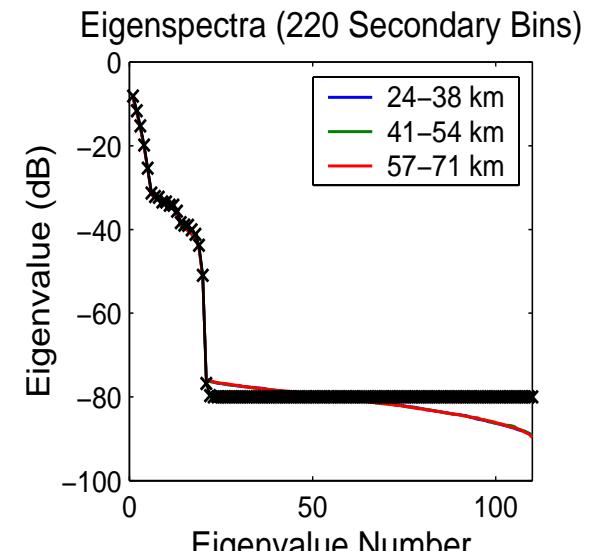
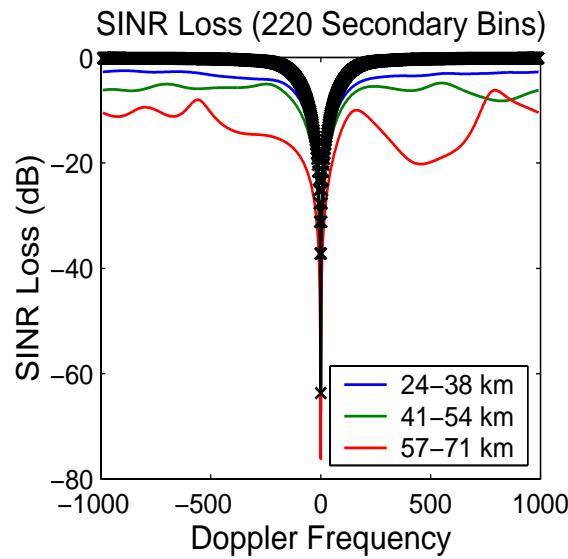


SINR Loss at Reference Range 30.4 km No Platform Crab

Bald Earth

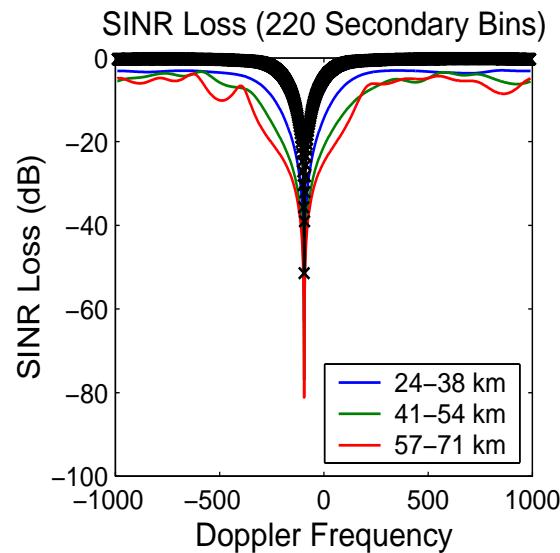


Site-Specific

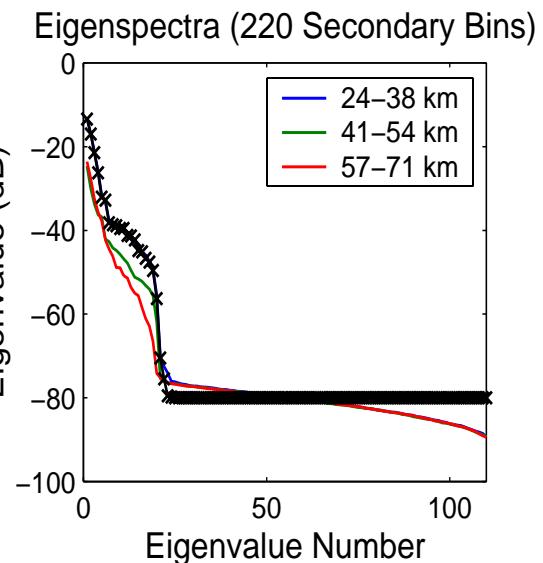
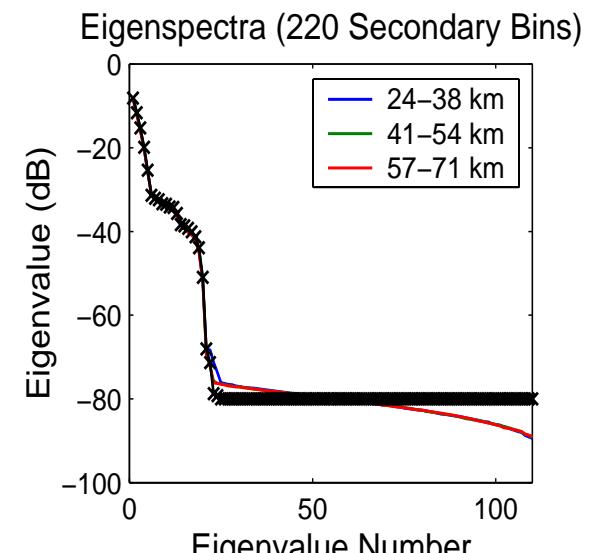
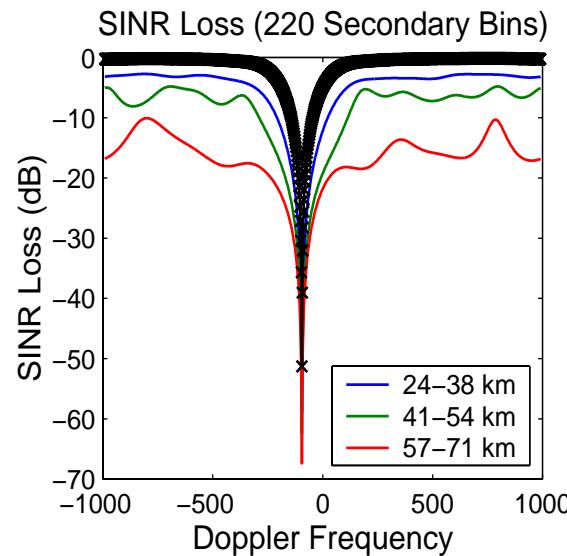


SINR Loss at Reference Range 30.4 km 7 Degrees Platform Crab

Bald Earth



Site-Specific



Computing Considerations

- Large maps in varying formats require considerable processing to create clutter map
 - Amenable to parallel processing prior to image fusion
- Realistic sensor array configurations (e.g. 100-1000 pulses and 10-100 elements) require considerable data storage and processing
 - Simulation of clutter for a given range and/or multiple ranges amenable to parallel or multi-threaded processing
- Several data sources providing similar information at varying scales are available, requiring quantification of the tradeoffs between increasing computational requirements versus improvements in signal processing metrics

Application in KASSPER Framework

- Algorithm development and benchmarking in realistic, heterogeneous clutter scenarios
 - Controlled environment allows determination of effects on algorithm performance due to change in specific parameters and environmental/platform conditions
- Pre-filtering or whitening of data with deterministic or knowledge-aided clutter response
- Intelligent secondary data sample selection and screening of data
- Land class specific ICM spectra models
- Quantification of effects of targets in secondary data in controlled scenarios

Summary

- STAP assumes availability of ample iid data
- Real clutter scenarios are heterogeneous and site-specific
- Important considerations for a knowledge-assisted front-end architecture include the following:
 - Cultural databases, and spatial information format and projection
 - Geographic Information System (GIS)
 - Relational database choice and database interconnectivity
- Site-specific, bald earth and MCARM measurements were compared for a scenario over the Delmarva Peninsula
- Elevation and land characterization data allow a good match between simulated and experimental MCARM measurements
- The effects of heterogeneous clutter and non-zero crab angles were discussed

References

- [1] Douglas J. Dudycha, "Introduction to Cartography and Remote Sensing", University of Waterloo, <http://www.fes.uwaterloo.ca/crs/geog165/index.htm>.
- [2] Rebecca Handcock and Carl Drouin, "Geographic Information Systems and Mapping I", University of Toronto, Summer 1998, http://eratos.erin.utoronto.ca/handcock/TA/GGR272_1998S/#Intro